Selati Tailings Dam New Decant Tower

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Abstract

A failure occurred along the Selati Tailings Dam decant outlet conduit in February 2013. Emergency response procedures ensured the integrity of the facility. Improved engineered remedial measures were then executed. A trade-off study was conducted to find the preferred option for replacement of the decant system. The outcome was that a gravity decant system similar to the existing system is preferred and is to be located on natural ground in the facility basin on the Southern side. The detail design was prepared for this 64 m tall concrete structure and standalone hybrid staircase. The system can be operated fully remotely and uses power delivered by batteries, charged from solar panels on the control room roof. Engineering support services and quality control services were provided during the complicated construction phase and various innovations applied. The system is complete, commissioned and fully operation.

Keywords: *Trade-off, decant, design, engineering support.*

1 Introduction

Foskor's Phalaborwa operation offices are located in the Limpopo Province, South West of the Phalaborwa town. The Selati Tailings Dam (STD) is located approximately at coordinates 24°02' South and 31°06' East, North of the Olifants River as indicated in Figure 1 below. The new decant tower is located on the southern part of the STD.

Figure 1. Selati Tailings Dam Location.

The Client appointed consulting engineers to carry out the design of the new decant tower system for the Selati Tailings Dam (STD) at Foskor Phalaborwa following the failure of the existing main decant outfall conduit in Feb 2013.

A trade-off study was completed in May 2013 to determine the optimum decanting solution for the STD to the end of 2050. Options considered included gravity decants, pumped decanting and siphoning. The preferred option was for a gravity decant tower of similar design to the old tower.

The new tower structure was positioned on the southern part of the tailings dam, on the only remaining natural ground within the TD basin. The decant pipe will gravitate supernatant water and process water from the tailings dam to the outlet where it will report into the existing return water dam (RWD) via an energy dissipator.

2 Trade-off

Various decant options were considered during the trade-off study, which included gravity, pumping, floating barge and siphoning options or combination thereof. A trade-off matrix system was used to weigh each option based on technical issues, economic issues and physical environmental aspects. The gravity decant system with its decant tower positioned on the south side of the Selati tailings dam obtained the highest score in the matrix and was therefore the recommended decant option.

3 Detail Design

The concrete tower is 64 m tall and was designed with a circular concrete base. It has four decant flow channels which will decant water from the pond on rotational basis. Each channel has 35 flow tubes that will be used during the operational life of the tower system. The unused tubes are pegged on the guard rail and as the pond level rises, the pegged tube will be dropped manually to become the next tube to decant water. The decant system can operate automatically without any human interference. The suspended platform, which is operated in the control room at the upper end of the tower, will be used to access the flow tube channels. The mild steel / stainless steel hybrid standalone staircase provides access to the suspended platform and control room.

3.1 Geotechnical aspects

The geotechnical site investigation included excavation of a number of test pits along the outlet pipe alignment and drilling of two rotary core drill holes in the tower area to investigate foundation conditions.

A number of samples were taken for laboratory testing. Laboratory testing comprised indicator tests (i.e. Gradings and Atterberg limits), determination of the compaction properties (i.e. Modified AASHTO maximum dry density tests and optimum moisture content) and California Bearing Ratio tests.

A site visit to the southern open pit at the mine was conducted to inspect the available dolerite rock material from the mining operations. Cored rock samples were taken from the drilled boreholes to determine the strength properties of the rock, i.e. Uniaxial Compressive Strength (UCS) tests and Uniaxial Compressive Strength tests with deformation measurements (UCM).

At the tower foundation position, very soft granite gneiss rock was encountered between the depth of between 2.4 m and 2.9 m in the drill holes. The granite-gneiss rock was found to be typically highly weathered, interlayered with very soft and soft rock, with an allowable bearing capacity of 750 kPa which exceeds 650 kPa required by the early design. It was therefore recommended that the tower should be founded at a depth of between 2.4 m and 2.9 m.

The design required Y32 dowels bars to be grouted into bedrock and cast into the tower base to improve stability.

As the design developed, it became apparent that a bearing capacity of 1 000 kPa was required. This necessitated a founding depth of between 5.3 m and 5.8 m. The outlet pipe line and associated 27 m deep cut had already been finalized by this time. Since the system could not be lowered this late in the design the void between the new founding level and the tower base was filled with mass concrete to form a plinth together with the dowels grouted and cast in.

3.2 Main structure

The structure was analysed using AUTODESK ROBOT STRUCTURAL ANALYSIS PROFESSIONAL 2014 (Robot). Robot is a structural analysis software package that uses Finite Element Analysis (FEA) to analyse concrete and steel structures.

The structure was designed to the General Engineering Specifications of Foskor Limited and adhere to the following design standards:

- SANS 10100:2000
- SANS 10160: 2011
- SANS 10162: 2005
- EN1993-1-8:2005

The design accounted for dead load (both the structure and mechanical equipment), live load, wind load, tailings down-drag and temperature loading. Various loading combinations were considered in accordance with SANS 10160-1:2011.

The following aspects were modelled and assessed: bending, shear, axial compression, deflection and slenderness.

3.3 Access

A platform providing access to the operational flow tubes is suspended just above the water level. The platform is raised to remain above the rising water level.

On the existing tower, access to the control room at the top of the tower was provided via 9 m sections of vertically mounted cat ladders, accessed from the suspended platform, with a safety cage providing fall protection. Intermediate platforms were provided between each 9 m section.

Following a Risk Assessment, it was decided that the cat ladder system is not suitable to be used on the new tower, primarily based on health and safety concerns.

The first alternative design considered a spiral staircase. Because the suspended platform has to be able to be operated from water level to the control room, the staircase central circular column could not be fixed to the concrete tower. Access from the staircase onto the platform would also only be possible where the stairs are adjacent to the platform. The central column in this concept proved to be too slender and this concept was abandoned.

The second concept was that of an elevator system. It would be battery driven and all safety aspects were given due consideration. This concept would require low capital expenditure and minimal operating cost. It was rejected by the client due to the rigorous inspection requirements of the DMR. They felt that the risk of non-conformances with the elevator causing stoppages on the rest of the mine outweighed the financial benefit of the system.

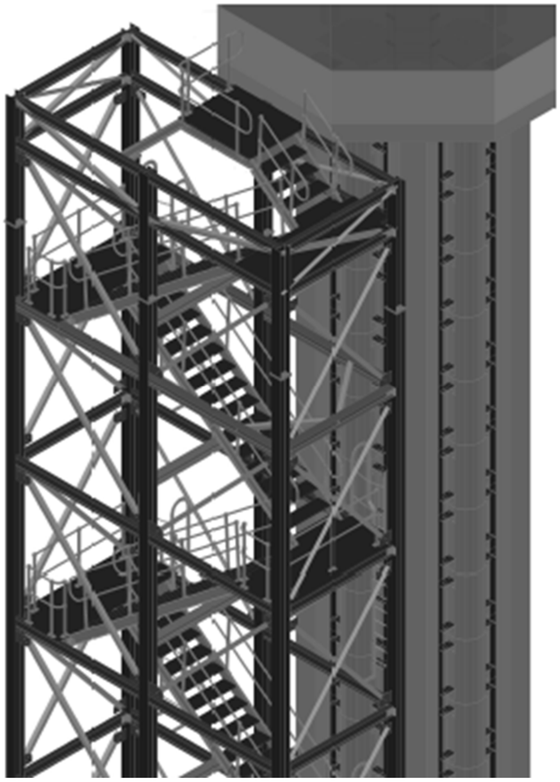

Figure 2. Hybrid staircase 3D-model.

Figure 3. Hybrid staircase under construction.

The third design concept employed a more conventional steel staircase structure. Again, the structure had to be completely free standing to allow the free movement of the suspended platform. The structure would also be inundated by the supernatant pool and deposited tailings over time. The structure was designed to withstand these conditions for at least the expected 37 year life of the tower.

The lower two thirds of the six main support columns are constructed from stainless steel, while corrosion protected mild steel was used for the upper third. This minimises the risk of corrosion of the members that could lead to failure of the structure. The upper third will be exposed to harsh conditions for a shorter period of time and was for that reason constructed in mild steel, resulting in a cost saving over stainless steel.

3.4 Pipe line

The design criteria required a maximum flow rate in the outlet system of 0.9 m^3/s.

The first 740 m of the 900 mm diameter concrete outlet pipe line was constructed in a cutting of up to 27 m deep, to ensure gravity discharge. The remaining 2 340 m of outlet pipe was constructed using an 800 mm diameter mild steel pipe line, placed above ground on precast concrete sleepers.

The concrete section of the outlet which will become buried under tailings with time comprise 900 mm diameter precast concrete spigot and socket pipes, used as a void former, encased in reinforced concrete of 1.2 x 1.2 m dimensions. This section of the outlet was designed to withstand the load of the tailings to the expected height of some 60 m to be reached in 37 years.

At the daylight point where the pipe line transitions from concrete to steel, an isolation valve was provided, able to withstand the maximum pressure head possible at the end of life of the tower. Operation of this valve will allow the mine to curtail flow of water and solids in the pipe line in case of a failure, thus preventing release of solids from the tailings dam.

The steel pipe line section was specified to be 800 ND Steel, 6 mm wall thickness with internal and external corrosion protection (Nordbak Nordcoat 6). The pipe route was aligned on the outer slopes of the tailings dam, aiming to follow the contours and maintain an even slope as much as practicable.

Air release valves were provided in key locations and concrete thrust blocks on all bends. An energy dissipator was provided on the outlet of the pipe line to allow discharge into the return water dam that will not damage or erode the dam wall.

4 Construction

The client appointed the consulting engineers to oversee the Quality Control/Quality Assurance (QC/QA) aspects during the construction phase of the new decant system and to provide engineering support.

QC refers to the following:

> Those actions taken by the Contractor’s team (or their subcontractors) to determine compliance of the various components of the excavation, materials and equipment sourcing, construction, installation, backfill, testing and commissioning activities with the requirements of the approved design; and

QA refers to the following:

Means and actions to independently assess conformity of the various components of the excavation, materials and equipment sourcing, construction, installation, backfill, testing and commissioning activities with the requirements of the approved design.

Engineering support services:

Addressing and technical matters arising during the construction process, performing design check or changes and amending construction drawings accordingly.

These tasks were complicated by the client dividing the project into three separate contracts. These were 1) the decant tower, 2) the sub-surface outfall pipe line and 3) the surface outfall pip line.

The following tasks were carried out on all three contracts: issuing of updated construction drawings and maintaining the drawing register, inspection and verification, commissioning and documenting and reporting.

The quality of the construction, installation and commissioning of the new decant system met the set standards, design specifications and performance objectives. The system was therefore declared ready for operation.

5 Innovations

A number of innovations were applied during the design phase and post start of construction works. A few are discussed in this section.

5.1 Hydropower concept

During the design, a conceptual hydro power generation system was considered. To facilitate implementation, the outlet pipe lines would have required a redesign, to upgrade them from gravity lines to pressure lines. The client chose not to implement the system.

The design considered a flow range of 0.45 – 0.9 m^3/s. A crossflow type turbine with asynchronous generator was considered, operational at 80% efficiency over the full flow range.

It was estimated that 2 472 – 2 966 MWh/a could have been generated. Considering the construction cost and electrical tariffs, an IRR of 36.6% was estimated.

5.2 Temporary pump tie-in

The temporary pump system which had been in operation since the failure in early 2013, had limited capacity due to the small diameter decant pipe. Tying into the new decant outlet pipe line earlier allowed for increased decanting from the facility.

This was made possible by the provision of a sweep-tee inlet, tying into the steel section of the outlet pipe near chainage 1 200 m. Once the pipe line from this point to the RWD had been completed, this inlet was commissioned.

Figure 4. Sweep-Tee pumped decant inlet.

5.3 Side inlet

At the time of completion of the decant system, the water level in the tailings dam was still approximately 2 m below the first intake level. As the mine was actively trying to reduce the pond volume and in the process of increasing the capacity of their beach irrigation system, it was challenging to estimate the time it would take for the water level to rise sufficiently to start decanting through the new tower.

The sooner this condition could be achieved, the sooner the costly pumping system can be decommissioned. To achieve this condition sooner, a side-inlet structure was designed and constructed at chainage 50 m along the concrete section of the outlet.

The inlet structure was design as a two-compartment structure. The inlet was fitted with a stainless-steel sluice gate, allowing control of flow into the first chamber. 4 No. 450 mm diameter pipes were installed through the chamber wall. Knife gate valves were installed to control the flow through individual inlets. A special insert was manufactured and installed into the concrete line, allowing flow through the four inlets, into the outlet pipe line. This special was then cast into the concrete encasement, like the rest of the concrete pipe section.

Once the tower flow tubes are decanting at a sufficiently high flow rate, the side-inlet will be decommissioned and filled with mass concrete.

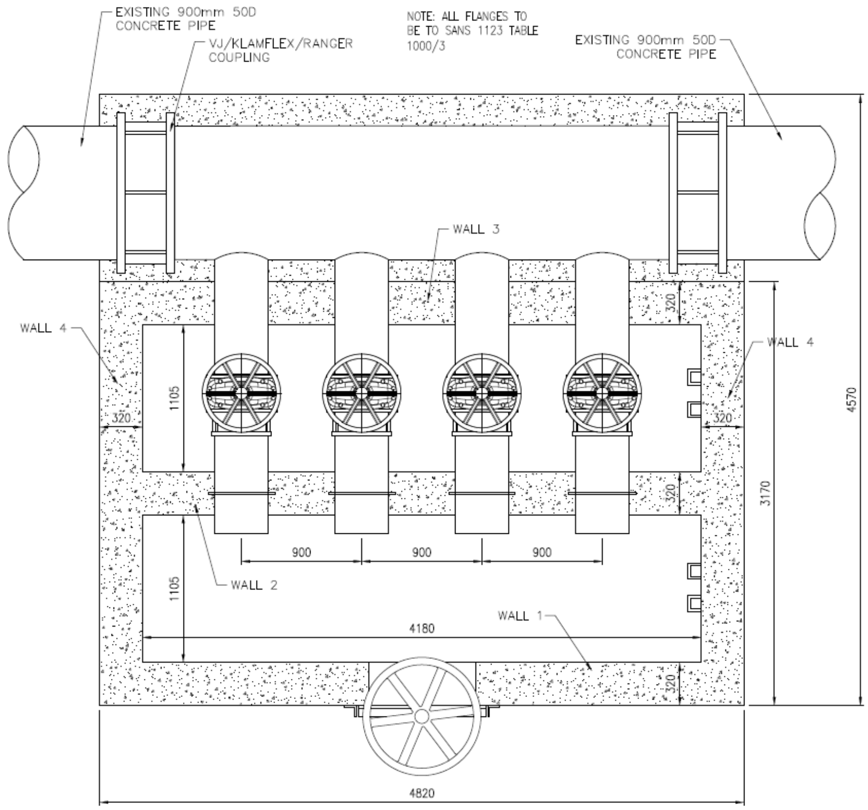

Figure 5. Side-inlet plan layout.

5.4 Partial backfill

The backfill design of the 27 m deep cut through the tailings dam perimeter was modified during construction to save on cost. The original design required reinstatement of the original ground profile.

Upstream of the crest, the backfill design was amended to the minimum required to ensure stability of the wall and protect the integrity of the bentonite seal zone in the backfill. The upstream slope was set to 1V:3H. The remainder will be backfilled with cyclone underflow or mechanical placement by trucking of coarse material borrow from the tailings beach area to protect the outlet pipe.

On the downstream side a slope of 1V:5H was created to align with the outer slope of the rest of the facility.

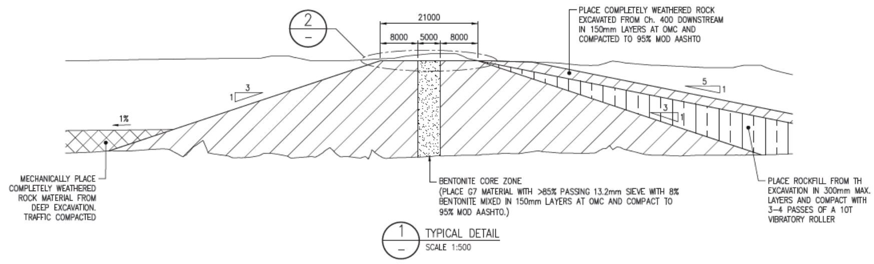

Figure 6. Typical section of the backfill design.

6 Conclusion

The consulting engineers demonstrated technical excellence throughout by supporting the client at each step along the way from addressing the emergency situation through to commissioning of the new decant system. An automatically operated decant system including tower, access staircase and outlet pipes were constructed on geotechnically improved ground while optimizing the backfill earthworks to reduce capital expenditure. Innovations were applied to reduce operational expenditure during the transition to the new system becoming fully operational. A hydropower system was also proposed.

7 Acknowledgements

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References

Loubser, A. L. and Strauss, A. J. 2018. Foskor Selati TSF – New decant system – Construction QA Report.
Knight Piésold Report RI301-00055/85-R1

Louwinger, F. and Lillie, E. 2014. Hydropower concept in the Selati dam decant system. Knight Piésold.

Strauss, A. J. and Grant-Stuart, D. J. 2013. Selati tailings dam decant system trade-off study. Knight Piésold Report RI301-55/51-R1

Strauss, A. J., Mazibuko, M. and Wilding, S. 2016. Selati decant tower design report. Knight Piésold Report RI301-00055/54/R1